

**Fuel Quality Impact On Heavy Duty Diesel
Emissions: A Literature Review
SAE 982649**

Rob Lee (Equilon Enterprises LLC,
on assignment from Shell Research Ltd)
Joanna Pedley (Equilon Enterprises LLC)
Chris Hobbs (Cummins Engine Company Inc.)

Worldwide Variation in:

- **Pool average diesel quality**
 - e.g. cetane
- **Market demands**
 - e.g. engine technology
- **Legislative demands and incentives**
 - e.g. Swedish class I diesel

Review of Emission Effects of:

- Sulfur
- Cetane
- Total Aromatics
- Polyaromatics
- Density
- Back End Volatility
- Oxygenates

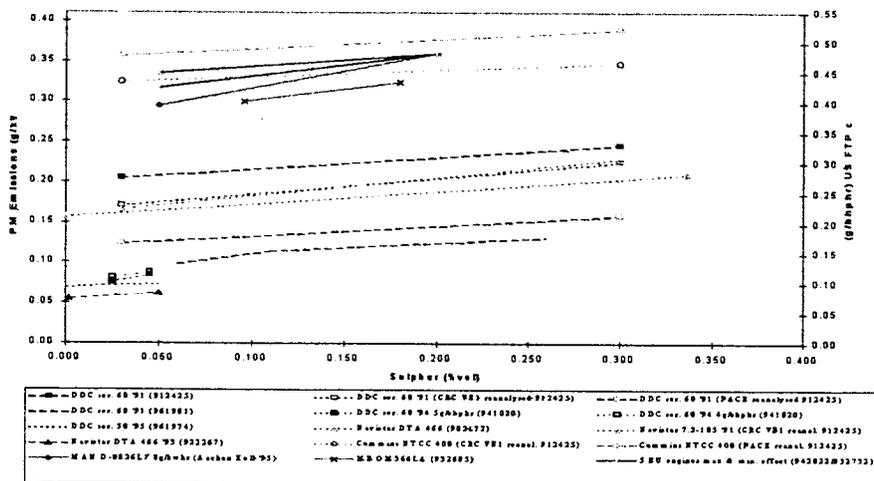
Scope

- Study limited to fuel quality effect of **REGULATED** emissions of heavy duty diesel engines.
- Predominately US 1991 through 1998 engines and Euro 1 (1993) through Euro 2 (1996) engines.
- Results taken from papers where full decoupling of fuel parameters achieved.
- Both US and EU cycle results plotted on same graphs to give overall trends and indication of fleet effects.
- Presentation focus on NO_x and PM emission effects.

Format of Plots

- EU R49 cycle results indicated by solid lines on graphs and read off left Y axis.
- US FTP cycle results represented by dotted line for combined cycle, dashed for hot cycle and read off right Y axis.
- Individual test engines have single line & data point colour coding throughout paper.

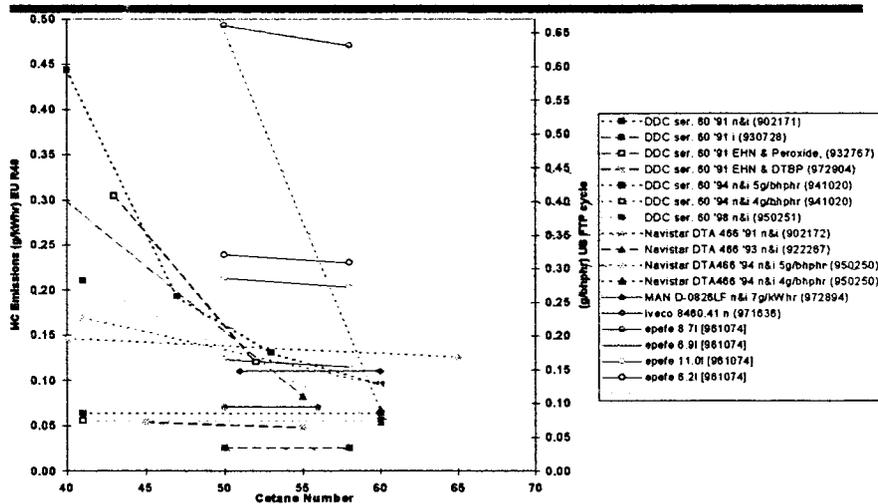
Sulfur Effects on PM Emissions



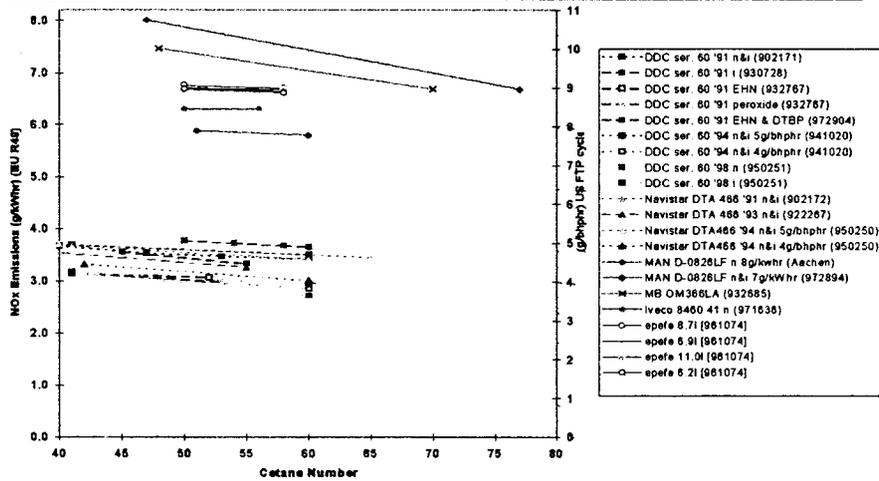
Sulfur Summary

- Reducing sulfur levels from 0.30% to 0.05% gives large benefits.
- In engines without aftertreatment, reducing sulfur to levels lower than 0.05% gives minimal incremental benefit.
- However, sulfur levels lower than 0.05% may be necessary as enabler for aftertreatment devices.
 - but then other fuel parameters will only have minor or secondary effects on emissions.

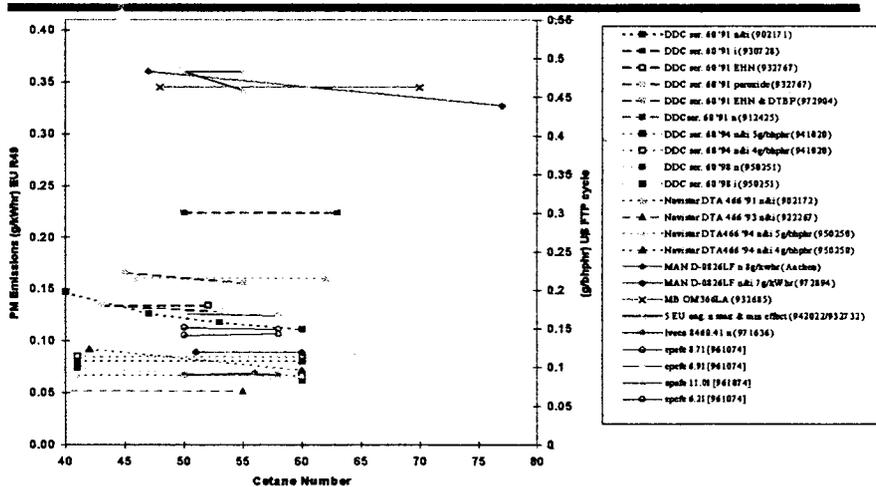
Cetane Effects on HC Emissions



Cetane Effects on NOx Emissions



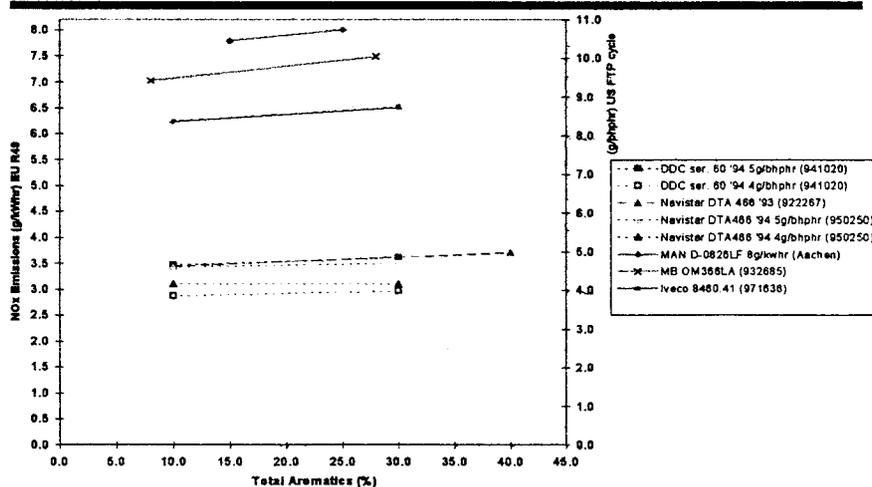
Cetane Effects on PM Emissions



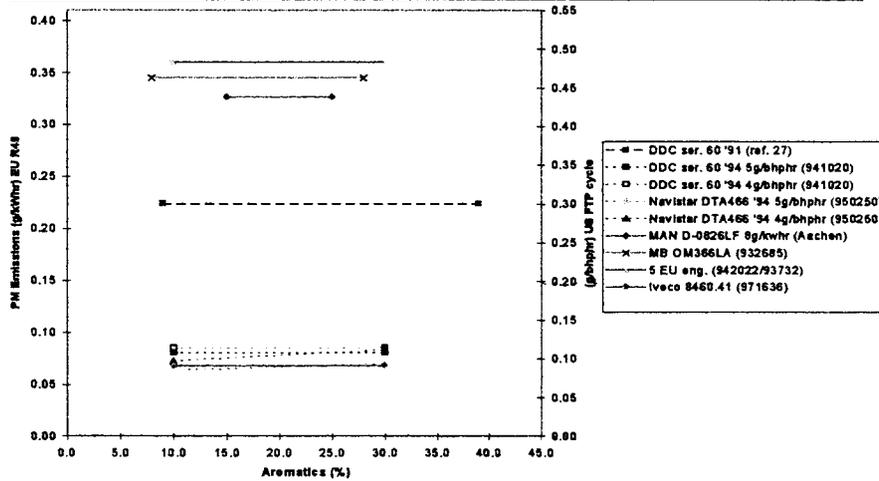
Cetane Summary

- Increasing CN gives small benefit in NO_x, however, in newer engines designed to have very little premixed burn this effect is likely to decrease or be non-existent.
- Effect on PM is variable but, in general, shows no effect.
- Effect of cetane on HC and CO is variable - increasing CN gives large benefit in high emission engines but no effect in low emission engines.
- No significant differences observed between natural and improved cetane fuels.

Aromatic Effects on NO_x Emissions



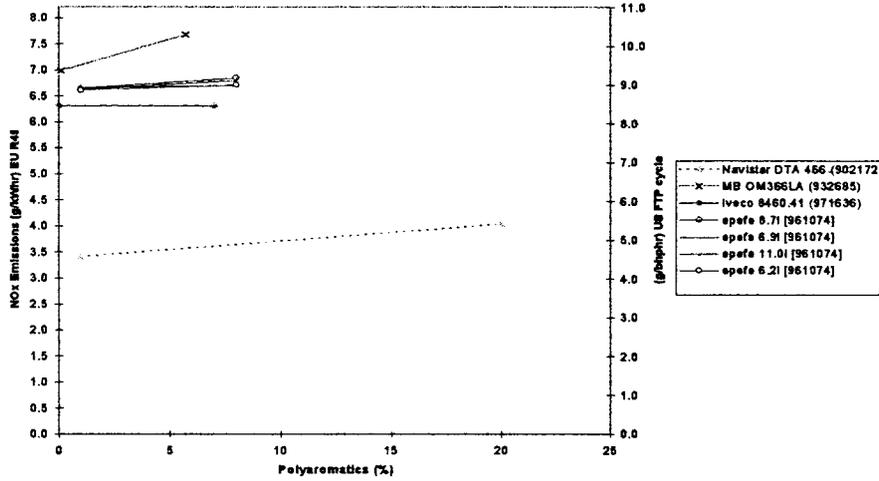
Aromatic Effects on PM Emissions



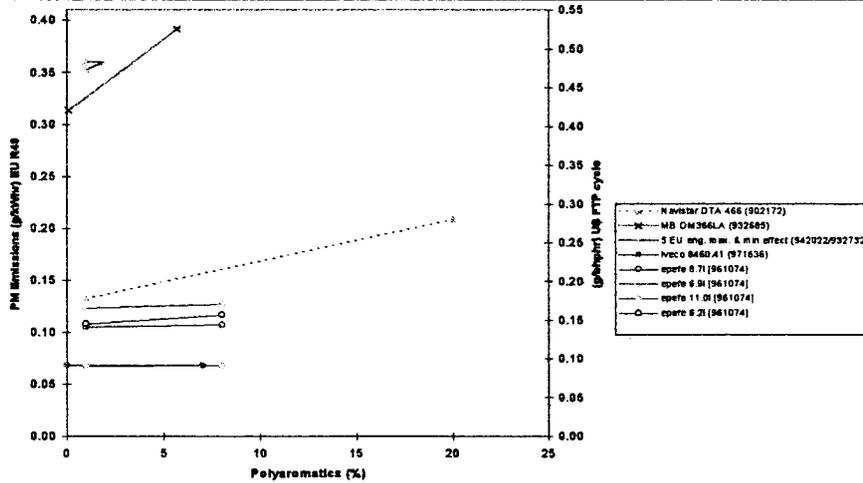
Total Aromatics Summary

- Large decreases in aromatics (from 30% to 10%) gives small (0-5%) reduction in NO_x emissions.
- Total aromatics have no effect on PM emissions.
- Total aromatics have no effect on HC or CO emissions.

Polyaromatic Effects on NOx Emissions



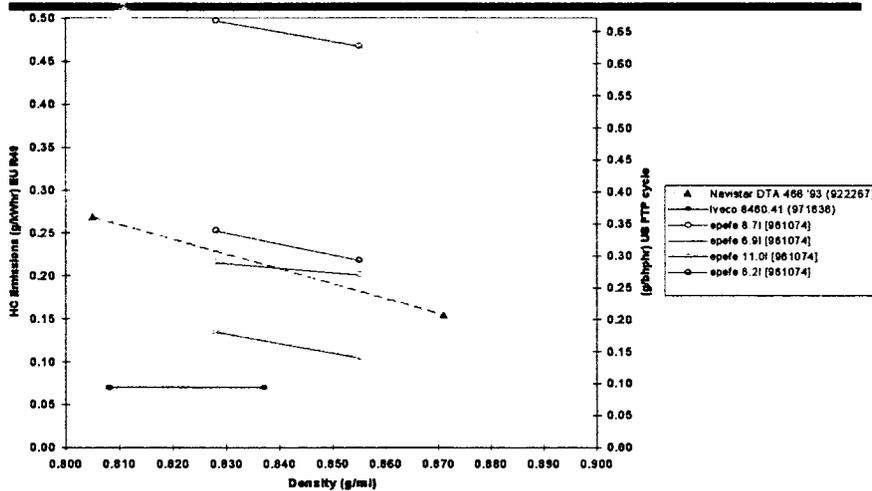
Polyaromatic Effects on PM Emissions



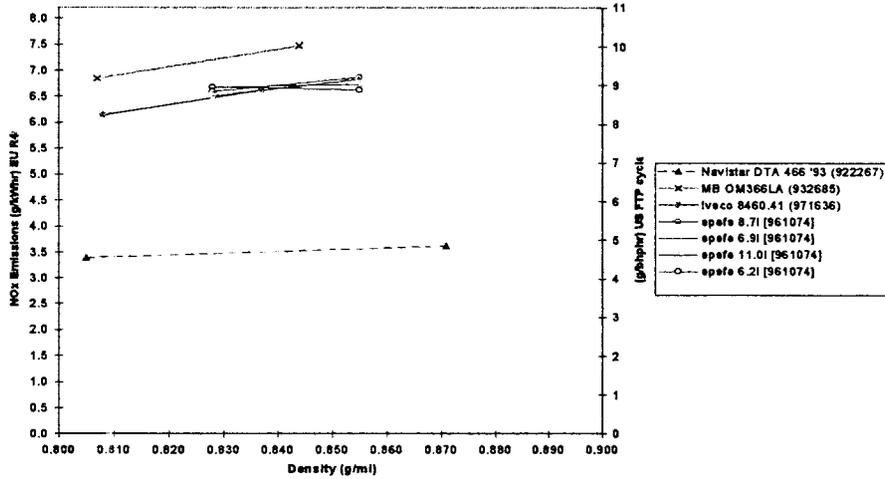
Polyaromatics Summary

- **Benefit in NO_x expected to be higher than for total aromatics.**
- **Reducing polyaromatics (from 10 to 0%) gives a small benefit in HC and NO_x emissions.**
- **Reducing polyaromatics gives large PM benefit in high emission engines but no effect in low emission engines.**
- **Polyaromatics have no effect on CO emissions.**

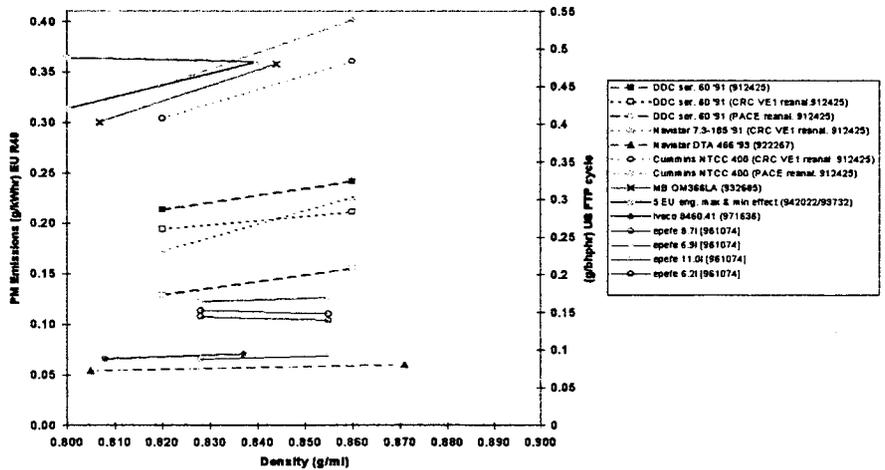
Density Effects on HC Emissions



Density Effects on NOx Emissions



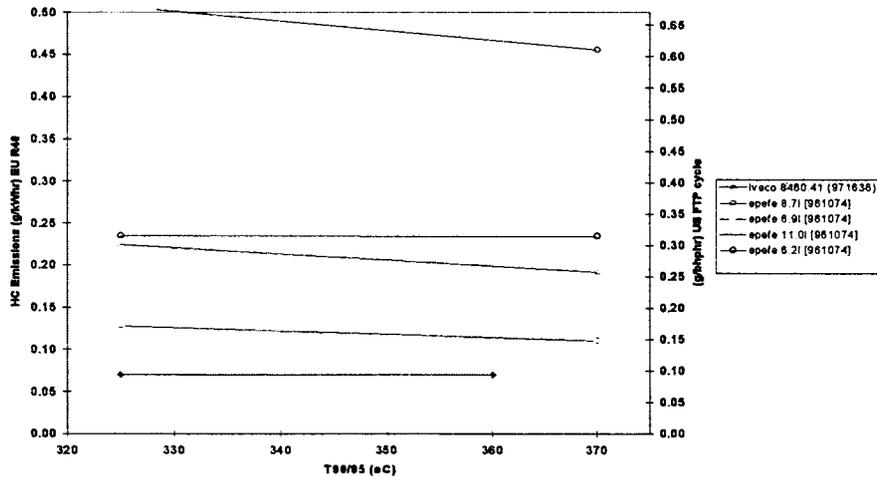
Density Effects on PM Emissions



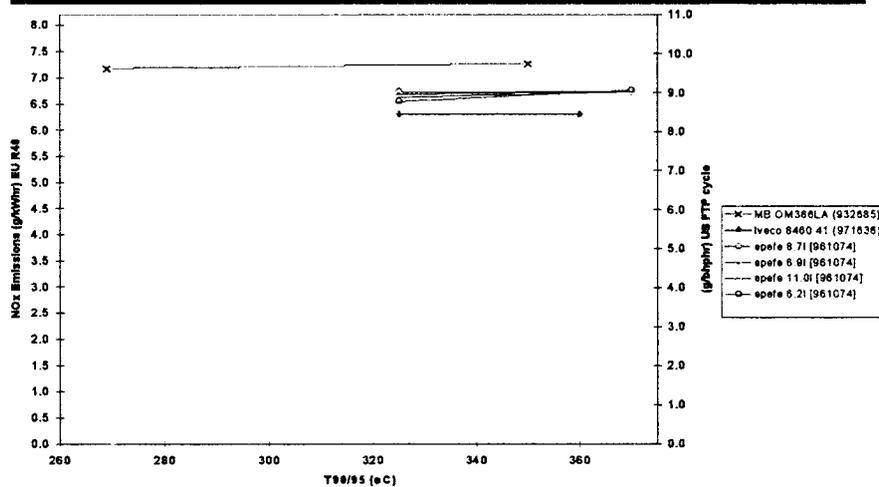
Density Summary

- Reducing density gives a small benefit in NO_x emissions.
- Reducing density gives large PM benefit in high emission engines but no effect in low emission engines.
- Reducing density gives a large increase in HC emissions.
- Reducing density gives a small increase in CO emissions.

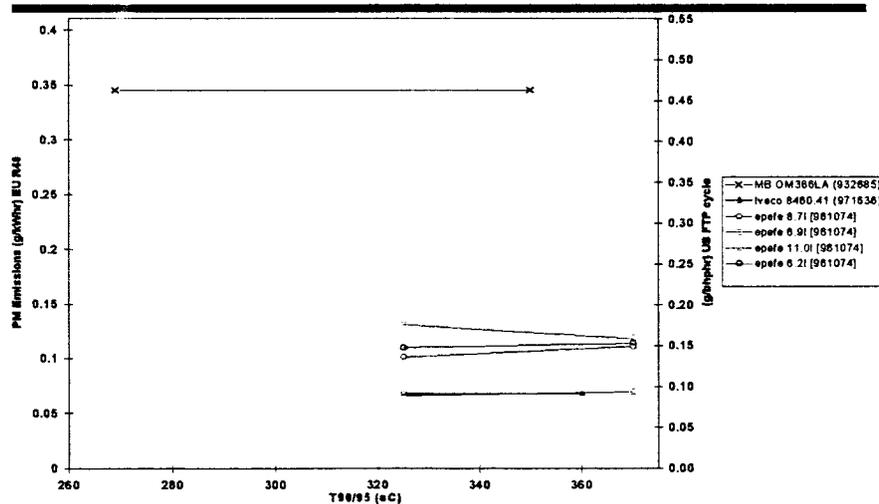
T90/95 Effects on HC Emissions



T90/95 Effects on NOx Emissions



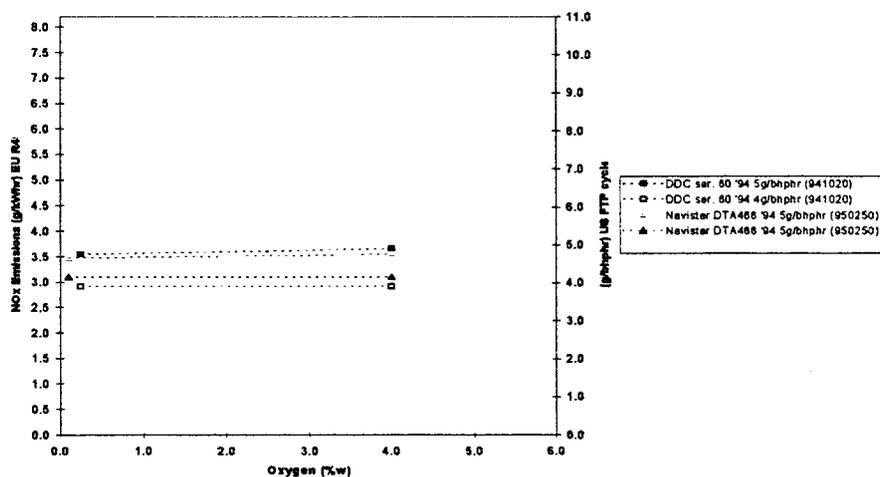
T90/95 Effects on PM Emissions



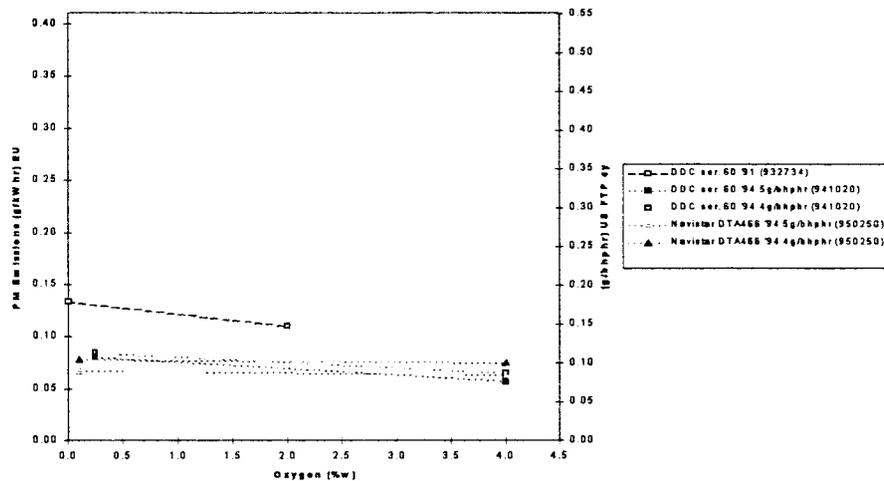
Back End Volatility Summary

- Back end volatility has only a very small effect on emissions. Any observed effect probably depends on the composition of the back end, e.g. low cetane polyaromatics vs high cetane heavy alkanes.
- Reducing T90/95 gives slight increase in HC and CO emissions.
- Reducing T90/95 gives slight benefit in NOx emissions.
- Reducing T90/95 has no effect on PM emissions.

Oxygenate Effects on NOx Emissions



Oxygenate Effects on PM Emissions



Oxygenate Effects on Emissions

- Due to the small number of fully decoupled fuel parameter studies and the narrow range tested (0-4%), oxygenate influences should be considered tentative until further work has been reported.
- May give small HC increase (high emission engines) but have no effect in low emission engines
- May slightly decrease CO emissions
- May have no effect on NOx emissions
- May give small decrease in PM emissions

Main Conclusions

- **Changes in engine technology impact how fuel parameters affect emissions,**
 - e.g. CN on HC, CO and NO_x, density or polys on PM.
- **Need to continue to build our understanding of fuel effects in new technology, e.g.:**
 - Low S may be required as aftertreatment enabler, however, then other fuel parameters will only have minor effect on emissions.
 - Technology (e.g electronic inj.) may minimise density effects.
- **Tests using fully decoupled fuel parameters are required in order ascertain the core effect,**
 - e.g. further work on oxygenates, using decoupled fuel parameters and a wider range of volume compositions.

Acknowledgements

- **Dave Britton (Shell International Petroleum Comp.)**
- **Richard Stradling (Shell Research Ltd)**
- **Richard Clark (Shell Research Ltd)**
- **Axel zur Loye (Cummins Engine Comp.)**
- **Yul Tarr (Cummins Engine Comp.)**
- **John Dec (Sandia National Lab.)**